

THE EFFECT OF SIGNED REINFORCEMENT AVAILABILITY ON CONCURRENT PERFORMANCES IN HUMANS

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During Phase I, three female human subjects pressed a button for monetary reinforcement in two-component concurrent variable-interval schedules. Five different reinforcement frequencies were used in component A, whereas the reinforcement frequency in component B was held constant. Absolute rates of responding conformed to equations proposed by Herrnstein to describe concurrent performances, and the ratios of the response rates and the times spent in the two components conformed to the matching law. During Phase II, the availability of reinforcement in component A was signaled by the illumination of a lamp. This resulted in suppression of response rates in component A and elevation of response rates in component B, these changes being reflected in a distortion of the matching relationship which took the form of a bias in favor of component B.

Key words: Herrnstein's equation, Matching Law, response rate, reinforcement frequency, changeover rate, signaled reinforcement availability, variable-interval, concurrent schedules, button pressing, humans

If an organism is exposed to a concurrent schedule consisting of two variable-interval (VI) components, A and B, the rate of responding in each component depends jointly upon the reinforcement frequencies in both components. Herrnstein (1970) has proposed equations of the following forms to describe behavior in concurrent schedules:

$$R_A = R_{max} \cdot r_A / (K_H + r_A + r_B), \quad (1)$$

$$R_B = R_{max} \cdot r_B / (K_H + r_A + r_B). \quad (2)$$

where R is response rate and r is reinforcement frequency; R_{max} and K_H are constants, R_{max} being the theoretical maximum response rate which can be generated in a VI schedule (Herrnstein, 1974) and K_H being the reinforcement frequency needed to obtain the half-

maximal response rate in a single VI schedule (Bradshaw, Szabadi, & Bevan, 1976).¹ If the values of R_{max} and K_H are assumed to be invariant between the two components, Equations 1 and 2 may be combined to yield the matching law (Herrnstein, 1970):

$$R_A/R_B = r_A/r_B \quad (3a)$$

or

$$R_A/(R_A + R_B) = r_A/(r_A + r_B). \quad (3b)$$

The matching law has been extensively confirmed in a variety of species (for review, see de Villiers, 1977).

Equations 1 and 2 predict that if the reinforcement frequency in Component B (r_B) is held constant, increasing values of r_A will be accompanied by increasing values of R_A (cf. Equation 1) and declining values of R_B (cf. Equation 2). These predictions have been confirmed in the case of pigeons (Catania, 1963; Davison & Hunter, 1976; Lobb & Davison, 1975) and humans (Bradshaw et al., 1976; Bradshaw, Szabadi, & Bevan, 1979). The suppressive effect of r_A on R_B could be due to either (a) the reinforcements delivered in Component A or (b) the increased response rate, R_A , generated in Component A. If the latter alternative were correct, it would have serious implications for Herrnstein's formulation because Equations 1 and 2 could then be regarded only as descriptions of a special

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¹For a single VI schedule, $R = R_{max} \cdot r / (K_H + r)$. Hence, $r = K_H$ when $R = R_{max}/2$. This mathematical definition of K_H bypasses the theoretical controversy surrounding the interpretation of this constant [cf. Herrnstein's (1970) " r_0 " and Catania's (1973) "C"]. For further discussion, see Bradshaw (1977) and Staddon (1977).

case and would not apply to any situation where response rate and reinforcement frequency are manipulated independently. Experimental evidence obtained with pigeons seems to favor the former alternative, however, since Catania (1963) found that signaling the availability of reinforcement in Component A—a procedure which reduced R_A to very low levels—produced little change in the suppressant levels of r_A upon R_B . Similarly, Rachlin and Baum (1969) observed that the rate of responding in Component A was inversely related to the duration of reinforcement whose availability was signaled in Component B. In a subsequent experiment, these authors (Rachlin & Baum, 1972) also showed that the same inverse relationship applied even if Component A and Component B were associated with the same response key, either when the availability of Component B reinforcement was signaled on the response key or when Component B reinforcements were delivered independently of responding. These observations indicate that, at least in the case of pigeons, the rate of responding in Component A plays little or no part in determining the suppressant effect of Schedule A on responding in Component B. The present experiment examined whether signaled reinforcement availability has the same effects on the behavior of humans in concurrent VI schedules as it has on the behavior of pigeons in these schedules.

METHOD

Subjects

Three female subjects, A.D. (53 yr old), M.W. (39 yr old), and S.W. (22 yr old), were recruited by advertisement from the domestic staff of this university. All were experimentally naive at the start of training and had had no previous instruction in psychology.

Apparatus

Experimental sessions took place in a small room. A diagram of the apparatus used has been published previously (Bradshaw *et al.*, 1979). The subject sat at a desk facing a sloping panel 40 cm wide and 30 cm in height. Mounted on the panel were three rows of indicator lamps, the upper row amber, the middle row blue, and the lower row white; the lamps in each row were numbered 1 through

5 from left to right. Below the row of white lamps was a digital counter, on either side of which was mounted an additional lamp—one green and one red. A button, which could be depressed by a force of approximately 6 N (600 g), was located in front of the panel. A relay situated behind the panel provided auditory response feedback.

Except on the first day of training, a small auxiliary box was also present on the desk. Mounted on this box were three lamps (from left to right: amber, blue, and white) and a button which could be depressed by a force of approximately 2 N (200 g).

Conventional electromechanical programming and recording equipment was situated in another room judged to be out of earshot from the experimental room.

Procedure

Table 1 summarizes the procedure for the entire experiment. The experiment consisted of two phases, as follow.

Phase I. On the first day of training the subjects were instructed as follows:

This is a situation in which you earn money. You earn money simply by pressing this button. Sometimes when you press the button the green light will flash on; this means you will have earned one penny. The total amount of money you have earned is shown on this counter. Every time the green light flashes, it adds one point to the total score. (Please ignore the red light; it will not apply to you in this experiment.) When operating the button, make sure you press hard enough. You can tell whether you have

Table 1
Summary of Procedure

Phase of Experiment	Schedules Used In Each Component	
	Component A (Main Box)	Component B (auxiliary box)
Phase I		
Session I	VI's* 1-5 (no signal)	
Sessions 2-16	VI's 1-5 (no signal)	Standard VI (no signal)
Phase II		
Sessions 17-31	VI's 1-5 (signal)	Standard VI (no signal)

*See text for values of individual VI schedules.

pressed hard enough by listening for a slight click coming from inside the box. Now look at these amber lights (you don't have to worry about the blue and white lights). When one of the amber lights is on, it means that you are able to earn money. At the beginning of the session, one of the lights will come on and stay on for 10 minutes, and throughout this time you may earn money. At the end of 10 minutes, the light will go off for 5 minutes, and during this time you should rest. After the rest period, another light will come on, again for 10 minutes, and you may earn some more money. Then there will be another rest period, and so on, until each of the five amber lights has been presented. At the end of the session we will take the reading from the counter and note down how much you have earned. You will be paid in a lump sum at the end of the experiment.

Each 70-min session consisted of a 10-min exposure to each of the five amber lights, successive exposures being separated by 5-min time-out periods. The lights were presented in a random sequence, with the constraint that each light occurred in a different ordinal position on successive days. The five amber lights were each associated with a different VI schedule. Constant probability schedules were used, as described by Catania and Reynolds (1968). The reinforcement frequencies specified by the schedules were as follows: (a) 445 reinforcements per hr (VI 8-sec); (b) 211 reinforcements per hr (VI 17-sec); (c) 70 reinforcements per hr (VI 51-sec); (d) 21 reinforcements per hr (VI 171-sec); and (e) 5 reinforcements per hr (VI 720-sec). Reinforcement consisted of a 100-msec illumination of the green light and the addition of one point to the score displayed on the counter.

On the second day of Phase I, the subjects received the following instructions:

From today onward, there will be a slight change in the situation. In addition to the main box, you can see that we have introduced this small extra box. Whenever one of the amber lights on the main box is on, you may, whenever you wish, change over to the amber light on the extra box. You changeover simply by pressing this button on the extra box; this turns the light on

the main box *off* and at the same time turns the light on the extra box *on*. In order to go back to the light on the main box, you just press the button on the extra box a second time. The button on the extra box is only for changing over; the button on the main box is the one you press in order to obtain money. Today and every day from now on, you will be able to change over to the extra amber light; you can ignore the blue and the white lights on the extra box (they will not apply to you at all in this experiment).

The amber light on the auxiliary box was associated with a standard VI schedule identical to that associated with amber light No. 3 on the main box (VI 51-sec; 70 reinforcements per hr). No restriction was imposed on the frequency with which subjects could change over from one component to another, and no changeover delay was employed. Phase I continued for 16 successive working days.

Phase II. On the first day of Phase II the subjects received the following instructions:

From today onward, there will be a slight change in the situation. I can't tell you exactly what it is, except to say that it concerns the middle white light on the main box. You can continue to ignore all the other white lights and the blue lights, as before.

During Phase II, white light No. 3 was illuminated whenever a reinforcement became available in Component A (the component associated with the main box). The light remained illuminated until the next response was emitted in Component A, causing the reinforcer to be delivered. Reinforcement availability was signaled in all five VI schedules used in Component A, but was never signaled in Component B (the schedule associated with the auxiliary box). Phase II continued for 15 successive working days.

RESULTS

The data obtained from all three subjects during the two phases of the experiment are presented in numerical form in the Appendix.

Phase I

The mean response rates (\pm standard error of the mean) recorded in each schedule during

the last three sessions of Phase I were calculated individually for each subject and were plotted against the delivered reinforcement frequency in Component A (r_A). [Throughout this paper, response rate refers to *overall* response rate (i.e., the number of responses emitted per unit session time) rather than *local* response rate (i.e., the number of responses emitted per unit time spent in a particular component)]. Curves having the forms defined by Equations 1 and 2 were fitted to the data by nonlinear regression analysis (Wilkinson, 1961). The data obtained from all three subjects are shown in Figure 1 (closed symbols, continuous lines). The index of determination (p^2) was calculated for the curves obtained from each subject. This value expresses the proportion of the variance in the y -values which can be accounted for in terms of x in a curvilinear function (Lewis, 1960; see also Bradshaw *et al.*, 1976).

In the case of each subject, the rate of responding in Component A (R_A) was an increasing, negatively accelerated function of reinforcement frequency in Component A (r_A). The values of p^2 were .991 (A.D.), .998 (M.W.) and .989 (S.W.). In the case of each subject the rate of responding in Component B (R_B) declined asymptotically with increasing values of r_A . The values of p^2 were .998 (A.D.), .993 (M.W.), and .980 (S.W.).

The ratios of the response rates in the two components (R_A/R_B) were plotted against the ratios of the reinforcement frequencies in the two components (r_A/r_B) using double logarithmic coordinates (Baum, 1974b). Best-fit linear functions were fitted to the data using the method of least squares. The results obtained are shown in the left hand column of Figure 2 (filled circles, continuous lines). In the case of two subjects (A.D., S.W.), the regression line had a slope greater than 1.0, although the deviation from unity was statistically significant only in the case of A.D. ($t(4) = 4.67$, $p < .01$). The regression line obtained from M.W. had a slope less than 1.0, but this deviation was not statistically significant. The line obtained from M.W. had an intercept which was significantly greater than zero ($t(4) = 2.79$, $p < .05$); however, the intercepts obtained from the remaining two subjects did not deviate significantly from zero. For all the subjects, the proportion of the variance accounted for by the regression equation was greater than

.97 (correlation index, r^2 ; see Figure 2 for individual values).

The right-hand column of Figure 2 shows the ratios of the times spent in the two components (T_A/T_B) plotted against the ratios of the reinforcement frequencies in the two components (r_A/r_B) on double logarithmic coordinates (Figure 2, filled circles, continuous lines). Only in the case of A.D. did the slope of the regression line deviate significantly from unity [$t(4) = 5.64$, $p < .01$], and only in the case of M.W. did the value of the intercept deviate significantly from zero [$t(4) = 2.80$, $p < .05$]. In every case, the proportion of the data variance accounted for by the linear function was greater than .98.

Figure 3 (closed circles) shows changeover rate plotted against the relative reinforcement frequency in Component A. In each subject there was a biconic relationship between changeover rate and relative reinforcement frequency, the highest changeover rates being associated with intermediate values of relative reinforcement frequency; this effect was most pronounced in the case of M.W.

Phase II

The results obtained from each subject during the last three sessions of Phase II are shown in Figure 1 (open symbols, broken lines). For all three subjects, the introduction of signaled availability of reinforcement in Component A was accompanied by a marked suppression of the rate of responding in Component A (R_A). The response rates of A.D. and M.W. were reduced to less than 10% of the rates observed in the corresponding schedules during Phase I; in the case of S.W., response rates were maintained at 30% to 40% of the rates observed during Phase I. Concomitant with this decline in their response rates in Component A, all three subjects showed marked increases in their rates of responding in Component B (R_B).

The ratios of the response rates in the two components (R_A/R_B) were plotted against the ratios of the reinforcement frequencies in the two components (r_A/r_B) on double logarithmic coordinates. The results obtained are shown in the left-hand column of Figure 2 (open symbols, broken lines). For each subject, the proportion of the data variance accounted for by the linear function was greater than .98. For all three subjects, there was a

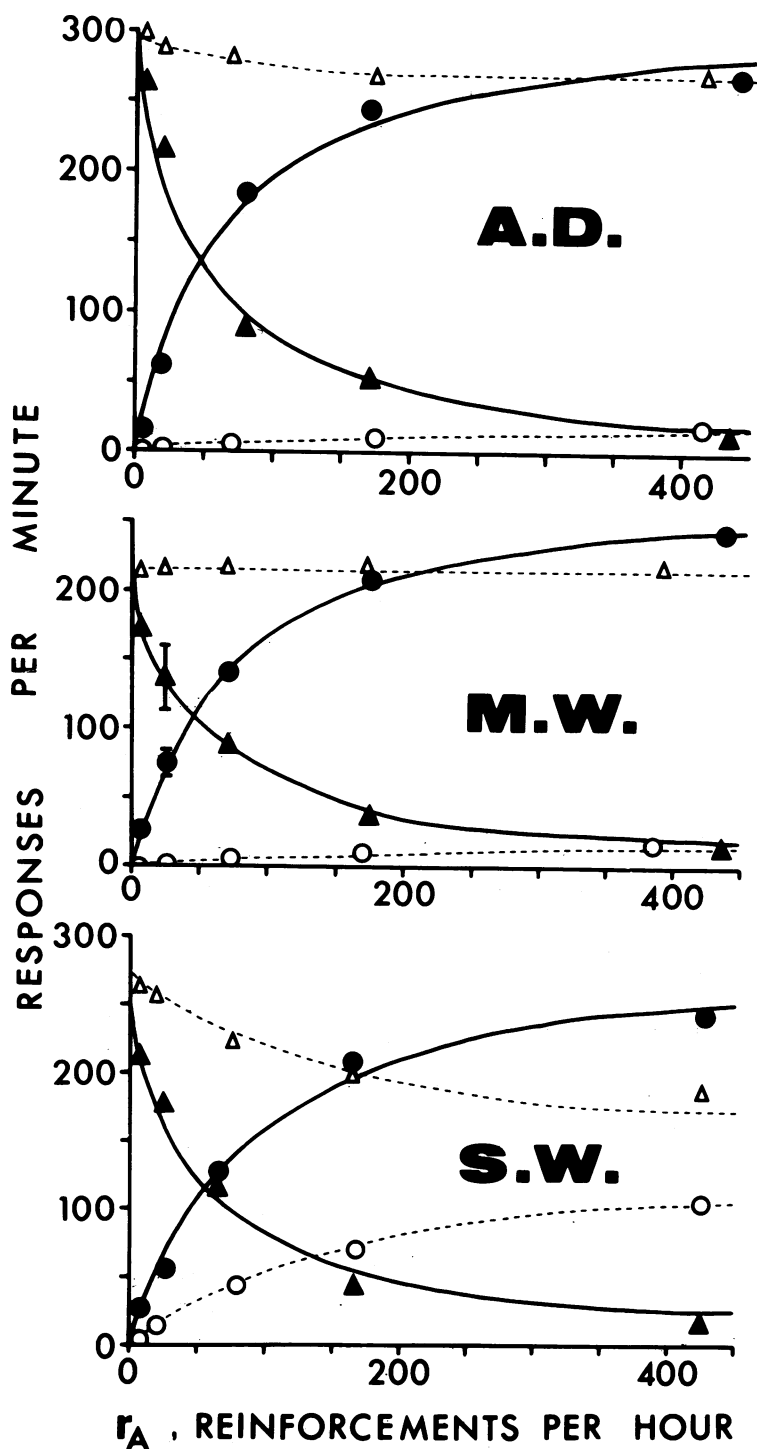


Fig. 1. Absolute response rates in Component A (R_A , circles) and Component B (R_B , triangles) plotted against delivered reinforcement frequency in Component A (r_A). Points are mean response rates (\pm s.e.m., where this was greater than ± 10 responses per min) for the last three sessions of Phase I (closed symbols, continuous lines) and the last three sessions of Phase II (open symbols, broken lines). During Phase II, the availability of reinforcement in Component A was signaled. Curves are best-fit rectangular hyperbolae, fitted by nonlinear regression analysis.

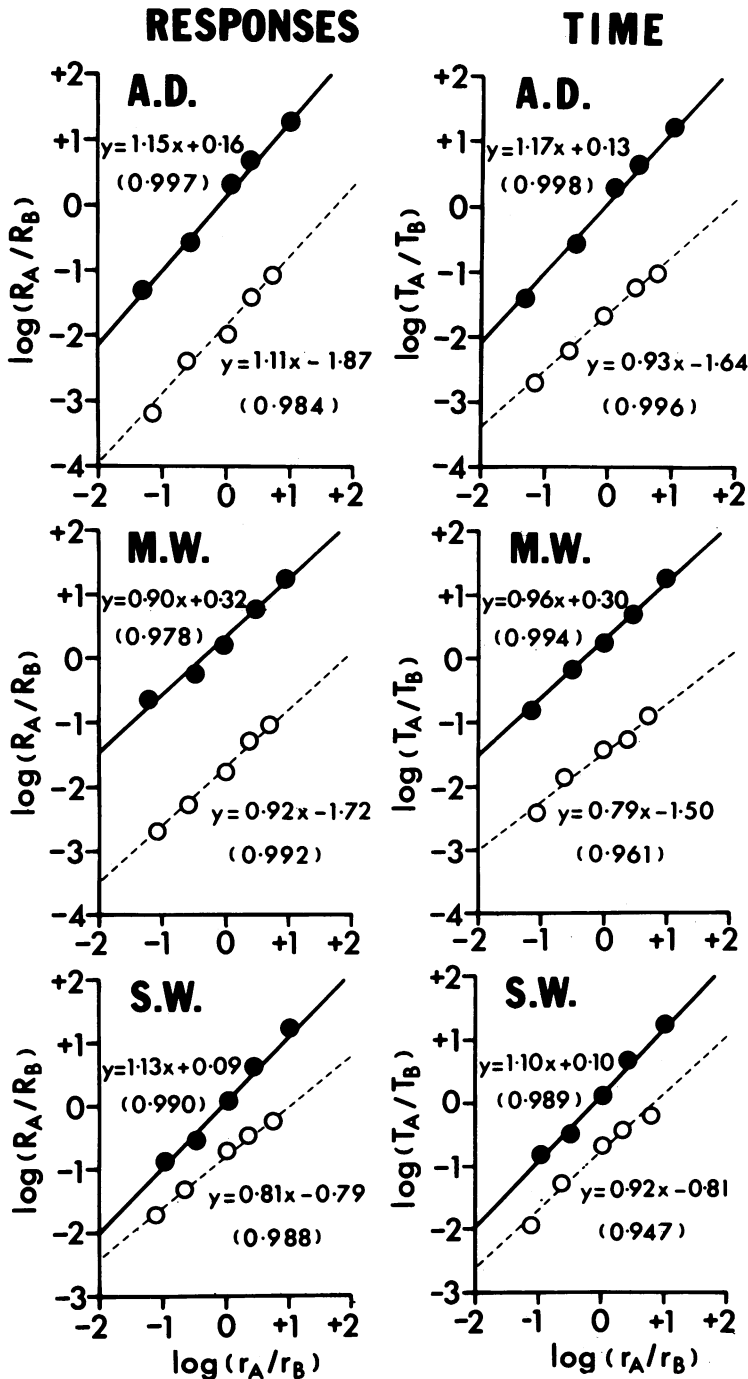


Fig. 2. *Left-hand graphs:* Ratios of response rates in the two components (R_A/R_B) plotted against ratios of reinforcement frequencies in the two components (r_A/r_B) using double logarithmic coordinates. Filled circles show the data obtained in Phase I (continuous lines are best-fit linear functions obtained by least-squares method). Open circles show data obtained in Phase II, when reinforcement availability in Component A was signaled (broken lines are best-fit linear functions obtained by least-squares method). Equations for linear functions are shown in each graph; numbers in parentheses are proportions of data variance accounted for by linear functions (r^2). *Right-hand graphs:* Ratios of times spent in the two components (T_A/T_B) plotted against ratios of reinforcement frequencies in the two components (r_A/r_B) using double logarithmic coordinates. Conventions as in left-hand graphs.

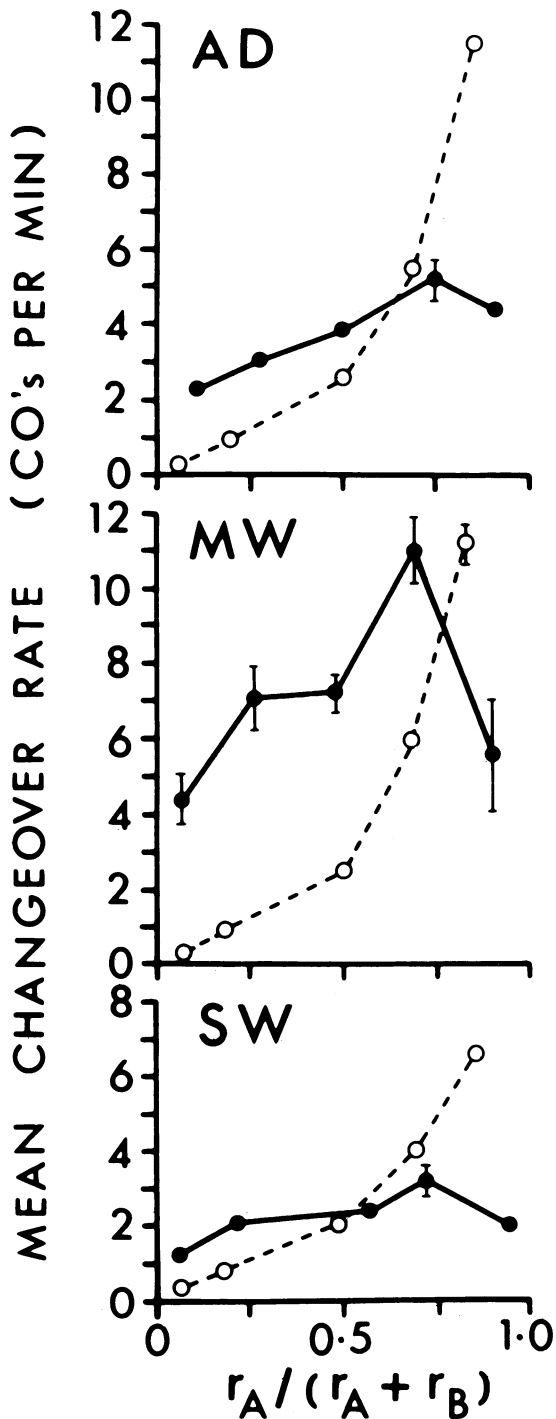


Fig. 3. Changeover rate plotted against relative reinforcement frequency in Component A. Points are mean changeover rates (\pm s.e.m., where this was greater than ± 3 changeovers per min) for the last three sessions of Phase I (closed symbols, continuous lines) and the last three sessions of Phase II (open symbols, broken lines).

statistically significant reduction in the value of the intercept of the regression line compared to the value obtained during Phase I [A.D., $t(8) = 10.72$, $p < .001$; M.W., $t(8) = 9.74$, $p < .001$; S.W., $t(8) = 4.83$, $p < .01$]. In no case was the slope of the linear function significantly altered from the slope obtained during Phase I.

Since the rates of responding maintained in Component A were very low during Phase II, the relationship between response rate ratios and reinforcement frequency ratios could have been an artifactual result of a close concordance of response rate to delivered reinforcement frequency (for discussion, see de Villiers, 1977). The double logarithmic analysis was therefore repeated after excluding all reinforced responses from the calculation of response rates. The best-fit linear functions produced by this analysis were $y = 1.12x - 1.99$ (A.D.), $y = .91x - 1.86$ (M.W.), and $y = .81x - .79$ (S.W.). In no case did the slope of the linear function deviate significantly from the slope obtained during Phase I.

In the right-hand column in Figure 2 are shown the ratios of the times spent in the two components (T_A/T_B) plotted against the ratios of the reinforcement frequencies in the two components (r_A/r_B) (Figure 2, open symbols and broken lines). For all subjects, the proportion of the data variance accounted for by the linear function was greater than .94. As was the case with the response rate ratios, all three subjects showed a significant reduction of the values of the intercepts compared to the values obtained in Phase I [A.D., $t(8) = 20.41$, $p < .001$; M.W., $t(8) = 9.16$, $p < .001$; S.W., $t(8) = 3.00$, $p < .001$]. In no case was there a significant difference between the slopes obtained during Phase I and Phase II.

Figure 3 (open circles) shows changeover rate plotted against the relative reinforcement frequency in Component A. For each subject, changeover rate increased monotonically with respect to relative reinforcement frequency. Compared to the results obtained in Phase I, there was an increase in changeover rate at high values of relative reinforcement frequency and a decrease at low values of relative reinforcement frequency.

DISCUSSION

During Phase I, in the absence of signaled availability of reinforcement, the behavior of

all three subjects conformed closely to Equations 1 and 2. This is consistent with previous observations of the behavior of pigeons (Catania, 1963; Davison & Hunter, 1976; Lobb & Davison, 1975) and humans (Bradshaw *et al.*, 1976, 1979) in concurrent VI schedules.

The left-hand column of Figure 2 (closed symbols) shows the data obtained during Phase I in the form of ratios; the ratios of the response rates in the two components are plotted against the ratios of the reinforcement frequencies in the two components using double logarithmic coordinates. This method of display facilitates the recognition of two systematic deviations from perfect matching (cf. Equation 3a); a deviation of the intercept of the best-fit linear function from zero indicates a *bias* in favor of one of the component schedules, whereas a deviation of the slope of the linear function from unity indicates either *undermatching*, if the slope is less than 1.0, or *overmatching*, if the slope is greater than 1.0 (Baum, 1974b). Only one subject in the present study (M.W.) showed a significant bias, this being in favor of Component A; one subject (A.D.) exhibited a significant tendency toward overmatching. When the logarithms of the ratios of the times spent in the two components were plotted against the logarithms of the ratios of the reinforcement frequencies (Figure 2, right-hand column), straight-line functions were obtained, with similar deviations from perfect matching. These observations accord well with numerous findings obtained both with animals and with humans which lend support to the matching law (for review, see de Villiers, 1977).

During Phase II, the introduction of signaled availability of reinforcement in Component A had the effect of suppressing response rates in Component A and concomitantly elevating response rates in Component B. Thus, the present results obtained with humans differ from those obtained by Catania (1963) with pigeons. Catania found that signaled availability of reinforcement in Component A suppressed responding in Component A, but had little or no effect upon responding in Component B. However, apart from the different species used, there are procedural differences between the two studies which may have contributed to the different results obtained. In Catania's experiment, re-

inforcement availability in Component A was signaled by illumination of the changeover key; when reinforcement was not available in Component A, the stimulus associated with Component B was continuously present and the changeover key was inoperative. Thus, Catania's procedure allowed access to Component A only when reinforcement was available in that component. In our procedure, changeovers were not restricted and the subject could observe the signal when she was responding in either component. A somewhat different procedure was used in a recent experiment with pigeons by Marcucella and Margolius (1978): The signal for reinforcement availability in Component A never occurred when the subject was responding in Component B, but was presented on the response key as soon as the subject changed over to Component A. This procedure had effects similar to our procedure, since in three of four birds studied the reduced response rates in Component A were accompanied by increased response rates in Component B.

The procedure of signaling the availability of reinforcement in Component A suppressed responding in Component A without affecting the reinforcement frequency in Component A (r_A). Thus, the elevation of response rates in Component B seen by us and by Marcucella and Margolius (1978) seem at first sight to be irreconcilable with the predictions derived from Equations 1 and 2. However, it may be argued that the signal procedure does not provide a valid test of these predictions. Signaling reinforcement availability in Component A can be regarded as changing Component A from a simple VI schedule to a multiple schedule in which the absence of the signal is a stimulus associated with an extinction (EXT) schedule. Since the subjects spend more time in the absence of the signal than in its presence, they are for most of the session exposed to a concurrent VI EXT schedule. In these circumstances, Equation 2 actually predicts that the signal procedure will enhance responding in Component B (R_B), since in the absence of the signal r_A is reduced to zero. While this interpretation may enable the present results to be reconciled with Equations 1 and 2, it provides no explanation for the discrepancy between our results and those of Catania (1963), since a similar interpretation could also be applied to Catania's procedure.

Further experiments are needed in order to identify the procedural and/or species differences responsible for the divergent results of the two studies.

Previous studies of concurrent performances in animals have shown that changeover rate is lowest when there is a great discrepancy between the reinforcement frequencies in the two component schedules, and highest when the reinforcement frequencies in the two components are approximately equal (Baum, 1974a; Brownstein & Pliskoff, 1968; Catania, 1963; Herrnstein, 1961; Hunter & Davison, 1978). The results obtained in Phase I (Figure 3, closed circles) are qualitatively consistent with these observations, although it is noteworthy that in each subject the highest changeover rate occurred at relative reinforcement frequencies somewhat greater than .5. The presence of the signal procedure during Phase II altered the relationship between changeover rate and relative reinforcement frequency: For each subject, changeover rate during Phase II increased monotonically with respect to relative reinforcement frequency in the component in which reinforcement availability was signaled (Figure 3, open circles).

REFERENCES

- Baum, W. M. Chained concurrent schedules: reinforcement as situation transition. *Journal of the Experimental Analysis of Behavior*, 1974, 22, 91-101. (a)
- Baum, W. M. On two types of deviation from the matching law: Bias and undermatching. *Journal of the Experimental Analysis of Behavior*, 1974, 21, 231-242. (b)
- Bradshaw, C. M. Suppression of response rates in variable-interval schedules by a concurrent schedule of reinforcement. *British Journal of Psychology*, 1977, 68, 473-480.
- Bradshaw, C. M., Szabadi, E., & Bevan, P. Behavior of humans in variable-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1976, 26, 135-141.
- Bradshaw, C. M., Szabadi, E., & Bevan, P. The effect of punishment on free-operant choice behavior in humans. *Journal of the Experimental Analysis of Behavior*, 1979, in press.
- Brownstein, A. J., & Pliskoff, S. S. Some effects of relative reinforcement rate and changeover delay in response-independent concurrent schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 683-688.
- Catania, A. C. Concurrent performances: Reinforcement interaction and response independence. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 253-263.
- Catania, A. C. Self-inhibiting effects of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 517-526.
- Catania, A. C., & Reynolds, G. S. A quantitative analysis of the responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 327-383.
- Davison, M. C., & Hunter, I. W. Performance on variable-interval schedules arranged singly and concurrently. *Journal of the Experimental Analysis of Behavior*, 1976, 25, 335-345.
- de Villiers, P. A. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, 1977.
- Herrnstein, R. J. Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 267-272.
- Herrnstein, R. J. On the law of effect. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 243-266.
- Herrnstein, R. J. Formal properties of the matching law. *Journal of the Experimental Analysis of Behavior*, 1974, 21, 159-164.
- Hunter, I. W., & Davison, M. C. Response rate and changeover performance on concurrent variable-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1978, 29, 535-556.
- Lewis, D. *Quantitative methods in psychology*. New York: McGraw-Hill, 1960.
- Lobb, B., & Davison, M. C. Preference in concurrent interval schedules: A systematic replication. *Journal of the Experimental Analysis of Behavior*, 1975, 24, 191-197.
- Marcucella, H., & Margolius, G. Time allocation in concurrent schedules: The effect of signalled reinforcement. *Journal of the Experimental Analysis of Behavior*, 1978, 29, 419-430.
- Rachlin, H., & Baum, W. M. Response rate as a function of amount of reinforcement for a signalled concurrent response. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 11-16.
- Rachlin, H., & Baum, W. M. Effects of alternative reinforcement: Does the source matter? *Journal of the Experimental Analysis of Behavior*, 1972, 18, 231-241.
- Staddon, J. E. R. On Herrnstein's equation and related forms. *Journal of the Experimental Analysis of Behavior*, 1977, 28, 163-170.
- Wilkinson, G. N. Statistical estimations in enzyme kinetics. *Biochemical Journal*, 1961, 80, 324-332.

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APPENDIX

Response Rates and Changeover Rates for the Last Three Sessions of Phase I and Phase II

Subject	Phase of Experiment	Schedule Operating in Component A	Mean Response Rate (resp/min) \pm s.e.m.		Mean Changeover Rate (CO/min) \pm s.e.m.
			Component A (VI's 1-5)	Component B (Standard VI)	
A.D.	Phase I (no signal)	1	268.6 \pm 8.6	12.4 \pm 1.5	4.5 \pm .1
		2	245.5 \pm 9.5	52.8 \pm 9.7	5.2 \pm .5
		3	185.1 \pm 10.7	85.5 \pm 9.5	3.9 \pm .3
		4	62.2 \pm 3.4	214.3 \pm 10.2	3.1 \pm .3
		5	13.3 \pm 3.4	261.5 \pm 6.8	2.4 \pm .2
	Phase II (signal in Component A)	1	20.6 \pm 1.3	269.7 \pm 4.9	11.5 \pm .2
		2	10.4 \pm .6	265.8 \pm 7.1	5.3 \pm .2
		3	3.8 \pm .2	273.9 \pm 5.1	2.5 \pm .1
		4	1.4 \pm .2	285.4 \pm 5.3	0.9 \pm .1
		5	0.2 \pm .2	297.2 \pm 6.4	0.3 \pm .1
M.W.	Phase I (no signal)	1	245.5 \pm 9.9	14.7 \pm 6.2	5.4 \pm 1.6
		2	207.0 \pm 10.6	34.7 \pm 5.1	11.0 \pm .9
		3	139.2 \pm 8.8	83.0 \pm 6.9	7.3 \pm .5
		4	74.3 \pm 14.6	134.3 \pm 23.8	7.2 \pm .9
		5	28.8 \pm 2.8	169.0 \pm 12.2	4.7 \pm .6
	Phase II (signal in Component A)	1	18.4 \pm .5	217.0 \pm 4.2	11.1 \pm .4
		2	11.2 \pm 1.4	213.9 \pm 6.6	5.9 \pm .2
		3	3.8 \pm .2	217.5 \pm 5.5	2.5 \pm .1
		4	1.2 \pm .3	216.9 \pm 12.7	0.8 \pm .2
		5	0.4 \pm .2	212.6 \pm 5.7	0.3 \pm .1
S.W.	Phase I (no signal)	1	241.7 \pm 1.5	13.2 \pm 2.2	2.1 \pm .3
		2	209.4 \pm 7.7	40.1 \pm 1.0	3.2 \pm .4
		3	126.6 \pm 7.0	179.3 \pm 6.3	2.4 \pm .2
		4	54.0 \pm 6.3	113.7 \pm 10.4	2.3 \pm .1
		5	27.4 \pm 12.0	206.8 \pm 18.6	1.4 \pm .2
	Phase II (signal in Component A)	1	104.2 \pm 2.1	180.4 \pm 4.2	6.5 \pm .2
		2	70.4 \pm 1.4	199.1 \pm 3.1	4.0 \pm .2
		3	40.7 \pm 1.2	223.7 \pm 4.0	2.1 \pm .2
		4	13.2 \pm 2.9	254.8 \pm 8.9	0.8 \pm .0
		5	5.3 \pm .6	260.9 \pm 4.2	0.4 \pm .0